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(71) Applicant: **Bose Corporation**
Framlingham, Massachusetts 01701-9168 (US)

(72) Inventors:
- **Carreras, Ricardo F.**
  01701-9168, Framingham (US)
- **Lin, Lifun**
  01701-9168, Framingham (US)

(74) Representative: **Brunner, Michael John et al**
Gill Jennings & Every
Broadgate House
7 Eldon Street
London EC2M 7LH (GB)

(54) Method of restoring performance of a fuel cell by providing reverse current pulses and corresponding fuel cell system

(57) A system for operating a fuel cell comprises a fuel cell having an anode, an electrolyte and a cathode. An external power supply circuit connects the anode and cathode. There are a fi rst supplier for supplying a fuel to the anode, a second supplier for supplying oxidizer to the cathode, and a controller for intermittently providing reverse current charging to the fuel cell via the external power supply circuit.

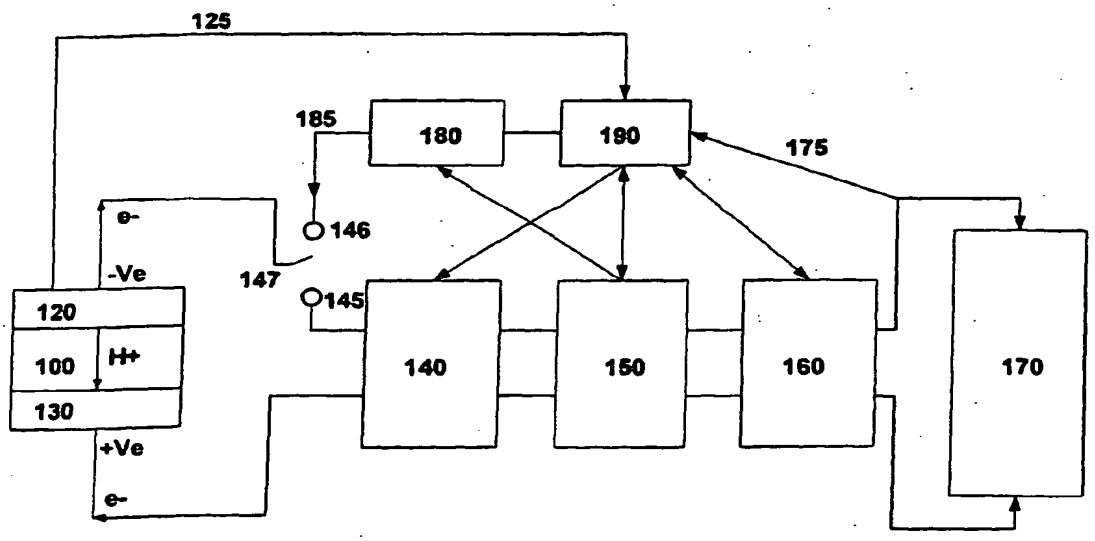

Figure 2

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Description

[0001] The present invention relates to fuel cells and more particularly concerns novel systems and methods for providing reverse current charging to a fuel cell.

BACKGROUND OF THE INVENTION

[0002] Fuel cells are electrochemical devices that produce usable electricity by converting chemical energy to electrical energy. A typical fuel cell includes positive and negative electrodes separated by an electrolyte (e.g., a polymer electrolyte membrane (PEM)). In a typical direct methanol fuel cell (DMFC), a fuel, such as hydrogen or methanol, supplied to the negative electrode diffuses to the anode catalyst and dissociates into protons and electrons. The protons pass through the PEM to the cathode, and the electrons travel through an external circuit to supply power to a load.

SUMMARY OF THE INVENTION

[0003] According to the invention, periodically interrupt operation of the fuel cell, and apply a reverse charging current to the cell during the interruption.

[0004] In another aspect, increase air flow rate at the ca thode.

[0005] In yet another aspect, the invention includes a power supply and energy storage device that provides reverse current charging to the fuel cell while supporting the load when fuel cell operation is interrupted, and during normal operation the fuel cell recharges the energy storage element.

[0006] Other features, objects, and advantages of the invention will be apparent from the following description when read in connection with the accompanying drawing in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 shows a system block diagram of an operating fuel cell in accordance with the invention;
FIG. 2 shows a graph of voltage versus time, which demonstrates the effect of pretreatment of a fuel cell using reverse current charging according to the invention;
FIG. 3 shows a graph of voltage versus time, which demonstrates the improvement in long-term decay of the fuel cell voltage using reverse current charging according to the invention;
FIG. 4 shows a graph of voltage versus time, which shows restoration of fuel cell voltage after cell reversal using reverse current charging according to the invention; and
FIG. 5 shows a graph of voltage versus time, which shows the improvement of fuel cell voltage using reverse current charging and an increase in cathode side air flow rate according to the invention.

[0008] Like reference symbols in the various views indicate like elements.

DETAILED DESCRIPTION

[0009] The method and system of the invention will be illustrated with reference to a direct methanol fuel cell (DMFC). However, the methods and system are applicable to any type of fuel cell including, but not limited to, fuel cells that utilize carbon based fuels, such as methanol and ethanol. It also applies to hydrogen fuel cells that utilize either pure hydrogen or hydrogen contaminated with carbon monoxide (CO) as fuel. Referring to FIG. 1, there is shown a system block diagram of a DMFC 110 in operation which methanol supplied to a negative electrode (anode) 120 that is electrochemically oxidized to produce electrons (e-) and protons (H^+). The protons move through an electrolyte 100 to the cathode 130. The electrolyte 100 can be in the form of a solid polymer electrolyte membrane (PEM). The electrons travel through the external circuit 200 (described below) to the positive electrode (cathode) 130, where they react with oxygen (or an oxidizer) and the protons that have been conducted through the PEM to form water and heat. Oxygen can be supplied to the cathode 130 by a variety of methods, such as, for example, flowing air or carrying via a liquid. An oxidizer can be used to oxidize and/or deliver oxygen via a fluid or gas to the cathode. Many possible oxidizers, for example, potassium chlorate ($KC10_3$) and sodium chlorate ($NaC10_3$), can decompose and release oxygen when heated. Hydrogen peroxide (in a liquid form) also can decompose and release oxygen when contacting catalyst or acid. Although these oxidizers can directly contact the cathode and react with electrons to complete the reduction reaction, they can also be decomposed first, and then released oxygen is delivered to cathode.

[0010] The electrodes are in contact with each side of the PEM and are typically in the form of carbon paper that is

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coated with a catalyst, such as platinum (Pt) or a mixture of platinum and ruthenium or a platinum-ruthenium alloy (Pt-Ru). The electrochemical reactions occurring at the anode and cathode can be illustrated as follows:

Anode (oxidation half-reaction)	$CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$
Cathode (reduction half-reaction)	$3/2\ O_2 + 6H^+ + 6e^- \rightarrow 3H_2O$
Net reaction	$CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2H_2O$

[0011] The electrons generated at the anode travel through the external circuit 200 that includes power processing circuitry and load circuitry (discu ssed below). The external circuit 200 includes an energy storage unit 150, which can include, e.g., a battery and/or capacitors. The energy from the fuel cell can be saved in the energy storage unit 150. The external circuit 200 optionally can include first intermediate power processing circuitry 140, which conditions the power from the fuel cell to properly supply the energy storage unit 150, if necessary. The first intermediate power processing circuitry can include, e.g., a DC/DC convertor. The energy saved in energy storage unit 150 can be used to feed load circuitry 170 (e.g., a portable electronic device) via optional second power processing circuitry 160. Second power processing circuitry 160 may provide further power conditioning on the output from 150 depending on the requirements of the load circuitry 170, and may include, e.g., a DC/DC or a DC/AC converter. The combination of first power processing circuitry 140, second power processing circuitry 160, and energy storage unit 150 provide power to the load circuit 170.

[0012] Fuel cell interruption can be provided by the interaction of power processing circuitry 180, second processing circuitry 160, energy storage unit 150, and control box 190. Circuitry 180 and control box 190 may comprise a hardwa re module, a software module, or combination thereof. The circuitry 180 draws power from energy storage unit 150 by providing a reverse current 185 to the fuel cell via switch or relay 147. Circuitry 180 provides reverse current to the fuel cell by injecting a current, which is opposite to the normal fuel cell discharge current. Therefore, during reverse current charging, the cathode potential is higher than during normal operation, and the anode potential is lower than during normal operation. Switch or relay 147 is connected to terminal 145 for normal fuel cell operation. Switch or relay 147 connects to switch terminal 146 during reverse current charging, and power from saved energy in energy storage unit 150 is provided to circuitry 180. Energy storage unit 150 continues to provide power to load 170 via second power processing circuitry 160 during reverse current charging. Control box 190 draws power from energy storage unit 150 and controls how circuit 180 provides reverse current pulses to the system. The reverse current charge is related to the number of reverse current pulses and the duration of each pulse, and depends on the fuel cell specification, fuel cell operation status, fuel cell performance, and external circuitry operating conditions. The control box 190 can provide periodic reverse current charging to the fuel cell to improve fuel cell performance depending on the fuel cell operating status (i.e., whether the fuel cell requires pretreatment, is in reversal condition, or has been operating for a long time and a decay in performance has been observed). Control box 190 monitors a variety of cell performance parameters, such as the fuel cell voltage, load current 175, power processing circuitry 160, and energy storage unit 150, fuel cell operating status via status line 125, fuel cell reversal by monitoring the fuel supply status, operating time elapse, and long-term performance decay.

[0013] The reverse current charge pulses applied to the fuel cell can be controlled per monitored parameters via circuitry 180 and switch or relay 147. For example, the control box 190 can disable power processing circuitry 140 during reverse current charging. When a decay in fuel cell output voltage is observed, control box 190 can initially provide a rapid series of reverse current pulses to the cell to increase the level of fuel cell power output. The reverse current pulses can then be adjusted to be less frequent as determined by monitored cell performance, i.e., due to an observed increase and stabilization in cell output. Generally, the fuel cell is constructed and arranged to provide steady power to the load circuitry 170, and the extra energy saved in the power supply 150 can be further used to satisfy peak power demand from the load circuit 170.

EXAMPLES

[0014] Membrane electrode assemblies (MEA) were fabricated or purchased from commercial sources. An MEA was tested in a single cell with 16cm^2 active area. The experiments were conducted using 1 M methanol solution and compressed air. The reverse current was typically the same as the load current. The duration of reverse current charging ranged from a few seconds to several minutes. During charging, the cell voltage was greater than the open circuit voltage, with the cathode under oxidation and the anode under reduction conditions.

[0015] MEA's were prepared as follows: Pt-Ru black (Johnson Matthey, London, UK) was mixed with a 5wt% NAFION solution (Electrochem Inc, Woburn, MA) and water to form an ink. The anode electrode was then prepared by applying a layer of th e obtained ink to a pre-teflonated (10wt%) carbon paper (Toray, Torayca, Japan). A similar process was used to prepare the cathode, except that the Pt was used instead of PtRu black (Johnson Matthey, London, UK). The

complete MEA was fabricated by bondin g the anode electrode and the cathode electrode to a NAFION® (Dupont, Wilmington, DE) membrane. The MEA was assembled for testing between two heated graphite blocks with fuel and air feed.

Example 1

[0016] This example demonstrates performance improvement via pretreatment of a fuel cell prepared in accordance with the invention. As demonstrated in FIG.2, after reverse current was applied briefly to a MEA, performance of the MEA after pre-treatment (curve (a) in FIG.2) improved significantly compared to the pe rformance prior to the brief reverse current charging pre-treatment (curve (b) in FIG.2).

[0017] The MEA was fabricated in-house with 4.5mg/cm^2 of Pt-Ru and 3mg/cm^2 of Pt. NAFION® N117 was used as the electrolyte membrane (Dupont, Wilmington, DE). The performance (output voltage) of the freshly made MEA was tested at 70 °C with 2 A loading, both before and after pre-treatment.

[0018] The pretreatment via brief reverse current charging was done as follows: the reverse current charging was carried out on the MEA by periodically applying a 2 A, 18 second reverse current pulse a total of six times over a 180 minute period. When not being reverse current charged, the cell output current was maintained at 2A. The power improvement was 15% (a 15% voltage improvement as shown in FIG.2 under constant output current conditions translates into a 15% power improvement). Note that power was provided by the cell at higher voltage after reverse current charging.

Example 2

[0019] This example demonstrates the effect of periodic reverse current charging on slowing down long-term fuel cell performance decay. Fuel cells are typically operated under constant load, i.e. in constant current mode. Long term operation in this mode results in a decay in the output voltage of the cell. In this example, the fuel cell operation was periodically interrupted manually and reverse current charging pulses were applied. In an operating system, these functions are provided by the system of FIG. 1, where switch 147 is periodically switched between positions 145 and 146 via circuitry 180 and control box 190.

[0020] The MEA tested was prepared with 2.2 mg/cm^2 Pt-Ru (Johnson-Matthey) on the anode side, 3.3 mg/cm^2 Pt on the cathode side, with a NAFION® N117 membrane. Teflonized Toray carbon paper was used as the gas diffusion electrode. The cell was tested at 42 °C and with 550 cc/min air flow. The fuel cell operation was interrupted via interrupting load current by disconnecting the fuel cell from the load (0.78A). During interruption, reverse current pulses were applied via an external power supply circuit.

[0021] The cell was tested for a first period of time with a current discharge/charge cycle of 0.81A /15 min discharge followed by -0.81A/ 0.3 min of reverse current charging. The cell was then further tested for a second period of time consisting solely of constant current discharge of 0.78A. The curve of FIG. 3 shows the output of the cell under test, for both periods of time. The cell experienced a performance decay of only 0.5mV/hr during the time in which periodic interruption and reverse current charging occurred vs. a performance decay of approximately 3mV/hr for period of time in which constant current operation was occurring.

[0022] Note that the current discharge for the period of time during which periodic r everse current charging was occurring was maintained at a higher level (0.81A) than it was during the period of time when the cell was operated under constant current load (0.78A). This is done to ensure that sufficient energy is available during the reverse current charging period to satisfy the load 170 and the energy demand from the reverse current charging circuit 180.

Example 3

[0023] This example describes restoration of fuel cell performance after cell reversal has occurred. During long term operation of a fuel cell, it is possible for the output voltage of one or more cells contained in a large cell stack to become reversed. When this occurs, the cell output voltage becomes negative. That is, during cell reversal, the anode becomes more positive than the cathode. One common cause for reversal is reactant depletion. Although cell reversal can be caused by depletion of reactants in either the anode or cathode, the greatest problem occurs when the anode fuel is restricted. For example, without fuel in the anode, carbon corrosion will occur and the anode catalyst can be damaged by excessive oxidation. The cell can be revived, however, using the current reversal procedure in accordance with the invention.

[0024] Cell reversal was simulated by occasionally operatin g a cell without fuel until the cell voltage became negative. It was discovered that by briefly applying a reverse current to the cell, the cell decay could be reduced and most of the cell performance could be restored.

[0025] An MEA was first tested with a defined load (discharge current), which is described below. After the cell voltage

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stabilized, the fuel pump was turned off, while forcing the same amount of current through the cell, for a period of time which was long enough to cause cell damage. The cell damage caused by cell reversal was determined to have occurred if the cell voltage after the fuel source was restored was lower than the original cell voltage under the same output current density condition.

[0026] The MEA was purchased from Lynntech (College Station, TX) with catalyst precoated on the membranes. The anode contained 4mg/cm^2 Pt -Ru, and the cathode contained 4mg/cm^2 Pt. This MEA was tested with teflonized carbon paper as the anode gas diffusion electrode and gold mesh as the cathode gas diffusion electrode using 600 cc/min of airflow. FIG. 4 shows the fuel cell performance curve (voltage vs. time) at 1A load at 70°C. After testing for a period of time (curve (a) in FIG. 4), the fuel delivery pump was turned off while the same amount of current was forced out of the cell. After a few minutes, the cell voltage became reversed (curve (b) in FIG. 4). The anode was more positive than the cathode with a cell voltage output of -1.7V. When the fuel pump was turned on and fuel delivery restored, the outpu t voltage was significantly lower than before cell reversal (curve (c) in FIG. 4). After applying a few brief reverse current charging pulses, most of the cell voltage was recovered (curve (d) in FIG. 4).

Example 4

[0027] This example describes combining reverse current charging with increased air flow rate. FIG. 5 shows the improvement of fuel cell voltage using reverse current charging along with an increase in the cathode side air flow rate.

[0028] Using the MEA prepared in Example 1, the reverse current charging was tested at an air flow rate of 200cc/min (curve (c) in FIG. 5) and 600cc/min (curve (a) in FIG.5). Before reverse current charging, the MEA had a lower voltage output at higher air flow rate. After reverse current charging, the MEA had a higher voltage o utput at higher air flow rate (curve (b) in FIG. 5) than the MEA at the lower air flow rate (curve (d) in FIG. 5).

[0029] There has been described novel apparatus and techniques for improving fuel cell performance. It is evident that those skilled in the art may now make numerous modifications of and departures from the specific embodiments described herein without departing from the inventive concepts. Consequently, the invention is to be construed as embracing each and every feature and novel combination of features present in or possessed by the apparatus and techniques herein disclosed and limited solely by the scope of the appended claims.

Claims

1. A method of chemoelectric generating with a fuel cell, having an anode, an electrolyte and a cathode comprisi ng:

   supplying fuel to said anode;
   supplying oxidizer to said cathode;
   intermittently providing reverse current charging to said fuel cell.

2. A method of chemoelectric generating in accordance with claim 1 and further including monitoring operating conditions of said fuel cell.

3. A method of chemoelectric generating in accordance with claim 2, wherein said reverse current charging occurs when monitoring operating conditions of said fuel cell indicates performance decay of said fuel cell.

4. A method of chemoelectric generating in accordance with claim 2 wherein said monitoring of fuel cell conditions includes monitoring the voltage of said fuel cell.

5. The method of claim 1, wherein said intermittently providing reverse current charging controls the amount of reverse current charge received by said fuel cell.

6. The method of claim 1, wherein said intermittently providing reverse current charging includes selecting a specific number of reverse current pulses and the duration of each reverse current pulse.

7. The method of claim 6 and further including monitoring operating conditions of said fuel cell selecting said specific number of reverse current pulses and duration of each pulse in accordance with the monitored fuel cell operating conditions.

8. The method of claim 1, wherein said intermittently providing reverse current charging increases the amount of charge received by said fuel cell when said monitored fuel cell performance deteriorates.

9. The method of claim 1, wherein said intermittently providing reverse current charging decreases the amount of charge received by said fuel cell when said monitored fuel cell performance improves.

10. The method of claim 1, wherein said supplying oxygen to said cathode is via air flowing.

11. The method of claim 10, wherein said intermittently providing reverse current charging further includes increasing the rate of air flowing when supplying oxidizer to said cathode.

12. The method of claim 1, wherein said supplying oxidizer to said cathode is via a liquid.

13. The method of claim 1, wherein said oxidizer is oxygen gas from air.

14. The method of claim 1, wherein said oxidizer is oxygen from decomposing potassium chlorate.

15. The method of claim 1, wherein said oxidizer is oxygen from decomposing sodium chlorate.

16. The method of claim 1, wherein said oxidizer is oxygen from decomposing hydrogen peroxide.

17. A method of pre-treating a fuel cell, comprising an anode, an electrolyte and a cathode with an external power supply circuit connecting said anode and cathode, said method comprising:

supplying methanol to said anode,
supplying oxidizer to said cathode,
and intermittently providing reverse current charging to said fuel cell via said external power supply circuit.

18. A method of restoring performance of a fuel cell comprising an anode, an electrolyte and a cathode with an external power supply circuit connecting said anode and cathode when said fuel cell is in reversal condition, said method comprising:

supplying a fuel to said anode,
supplying oxidizer to said cathode,
intermittently providing reverse current charging to said fuel cell via said external power supply circuit.

19. A method of operating a system having a fuel cell, said fuel cell comprising an anode, an electrolyte and a cathode, an external power supply circuit connecting said anode and cathode, and an external load circuit connecting said anode and cathode, said method comprising:

operating said fuel cell to provide power;
monitoring operating conditions of said system;
intermittently providing reverse current charging to sa id fuel cell via said external power supply circuit based on the monitored system operating conditions.

20. The method of claim 19, wherein said operating said fuel cell to provide power furnishes power to said external power supply circuit which further p rovides power to said external load circuit.

21. The method of claim 19, wherein said monitoring system operating conditions includes monitoring the performance of said fuel cell.

22. The method of claim 19, wherein said monitoring system operating conditions includes monitoring the operating condition of said fuel cell.

23. The method of claim 19, wherein said monitoring system operating conditions includes monitoring the operating condition of said external power supply circuit.

24. The method of claim 19, wherein said monitoring system operating conditions includes monitoring the operating condition of said external load circuit.

25. The method of claim 19, wherein said external power supply circuit provides power to said load circuit when se-

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lectively providing reverse current charging to said fuel cell.

26. A system for operating a fuel cell, comprising:

a fuel cell having an anode, an electrolyte and a cathode,
an external power supply circuit connecting said anode and cathode,
a first supplier for supplying a fuel to said anode;
a second supplier for supplying oxidizer to said cathode,
a controller for intermittently providing reverse current charging to said fuel cell via said external power supply circuit.

27. The system of claim 26, wherein said fuel cell consumes a carbon based fuel cell.

28. The method of claim 27, wherein said carbon based fuel cell is a direct methanol fuel cell (DMFC).

29. The system of claim 26, wherein said fuel cell is a hydrogen fuel cell.

30. The system of claim 29, wherein said hydrogen fuel cell utilizing pure hydrogen as fuel.

31. The system of claim 29, wherein said hydrogen fuel cell utilizing hydrogen contaminated with carbon monoxide (CO) as fuel.

32. The system of claim 26, wherein said controller is constructed and a rranged to monitor performance and operating status of said fuel cell.

33. The system of claim 26, wherein said controller is constructed and arranged to monitor said external load circuit current.

34. The system of claim 26, wherein said second supplier s upplying oxidizer to said cathode via air flowing.

35. The system of claim 26, wherein said second supplier supplying oxidizer to said cathode via a liquid.

36. The system of claim 26, wherein said oxidizer is oxygen gas from air.

37. The system of claim 26, wherein said oxidizer is oxygen from decomposing potassium chlorate.

38. The system of claim 26, wherein said oxidizer is oxygen from decomposing sodium chlorate.

39. The system of claim 26, wherein said oxidizer is oxygen from decomposing hydrogen peroxide.

40. A system for pretreating a fuel cell comprising:

a fuel cell having an anode, an electrolyte and a cathode,
an external power supply circuit connecting said anode and cathode,
a first supplier for supplying a fuel to said anode;
a second supplier for supplying oxidizer to said cathode,
a controller for providing reverse current charging to said fuel cell via said external power supply circuit.

41. The system of claim 40, wherein said fuel cell consumes a carbon based fuel.

42. The system of claim 41, wherein said carbon based fuel cell is a direct methanol fuel cell (DMFC).

43. The system of claim 40, wherein said fuel cell is a hydrogen fuel cell.

44. The system of claim 43, wherein said hydrogen fuel cell utilizes pure hydrogen as fuel.

45. The system of claim 43, wherein said hydrogen fuel cell utilizing hydrogen contaminated with carbon monoxide (CO) as fuel.

46. The system of claim 40, wherein said controller is constructed and arranged to monitor performance and operating status of said fuel cell.

47. the system of claim 40, wherein said second supplier supplying oxidizer to said cathode via air flowing.

48. The system of claim 40, wherein said second supplier supplying oxidizer to said cathode via a liquid.

49. The system of claim 40, wherein said oxidizer is oxygen gas from air.

50. The system of claim 40, wherein said oxidizer is oxygen from decomposing potassium chlorate.

51. The system of claim 40, wherein said oxidizer is oxygen from decomposing osdium chlorate.

52. The system of claim 40, wherein said oxidizer is oxygen from decomposing hydrogen peroxide.

53. A system for operating a fuel cell in reversal condition, comprising:

a fuel cell having an anode, an electrolyte and a cathode,
an external power supply circuit connecting said an ode and cathode,
a first supplier for supplying a fuel to said anode;
a second supplier for supplying oxidizer to said cathode,
a controller for intermittently providing reverse current charging to said fuel cell via said external power supply circuit.

54. The system of claim 52, wherein said fuel cell consumes a carbon based fuel.

55. The system of claim 53, wherein said carbon based fuel cell is a direct methanol fuel cell (DMFC).

56. The system of claim 52, wherein said fuel cell is a hydrogen fuel ce ll.

57. The system of claim 56, wherein said hydrogen fuel cell utilizes pure hydrogen as fuel.

58. The system of claim 56, wherein said hydrogen fuel cell utilizes hydrogen contaminated with carbon monoxide (CO) as fuel.

59. The system in claim 52, wherein said controller is constructed and arranged to monitor performance and operating status of said fuel cell.

60. A power system for converting fuel to electricity, comprising:

a fuel cell for generating the electricity, said fuel cell having an anode, an electrolyte and a cathode;
an external power supply circuit connecting said anode and cathode;
an external load circuit connected to said anode and cathode;
a controller for controlling said external power supply circuit to intermittently provide reverse current charging to said fuel cell.

61. The power system of claim 60, wherein said fuel cell consumes a carbon based fuel.

62. The power system of claim 61, wherein said carbon based fuel cell is a direct methanol fuel cell (DMFC).

63. The power system of claim 60, wherein said fuel cell is a hydrogen fuel cell.

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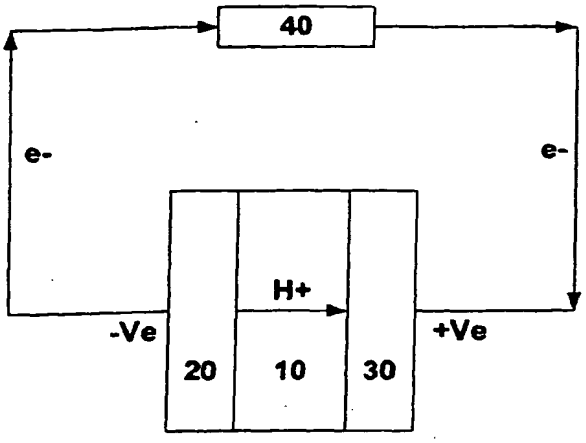

Figure 1

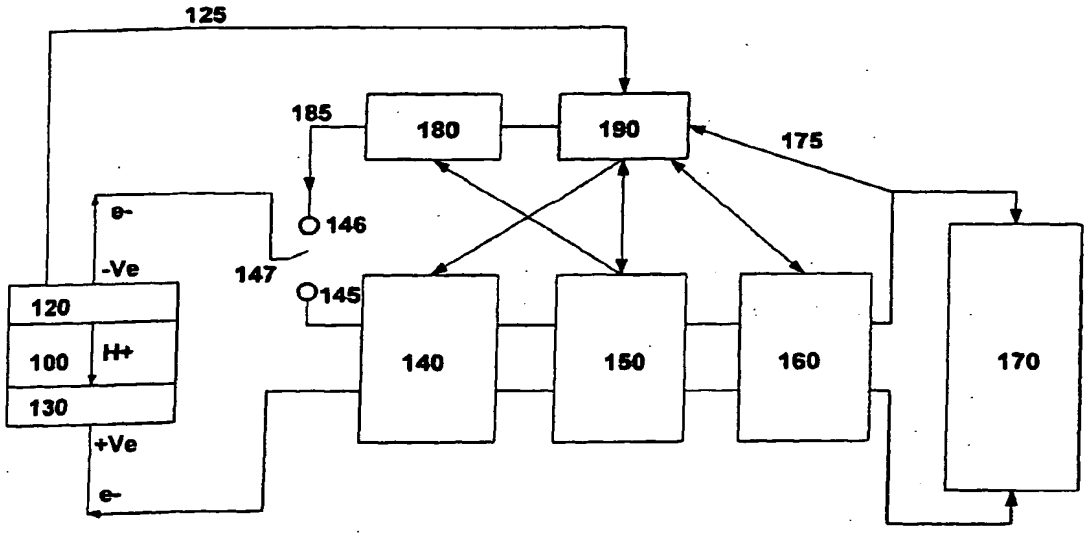

Figure 2

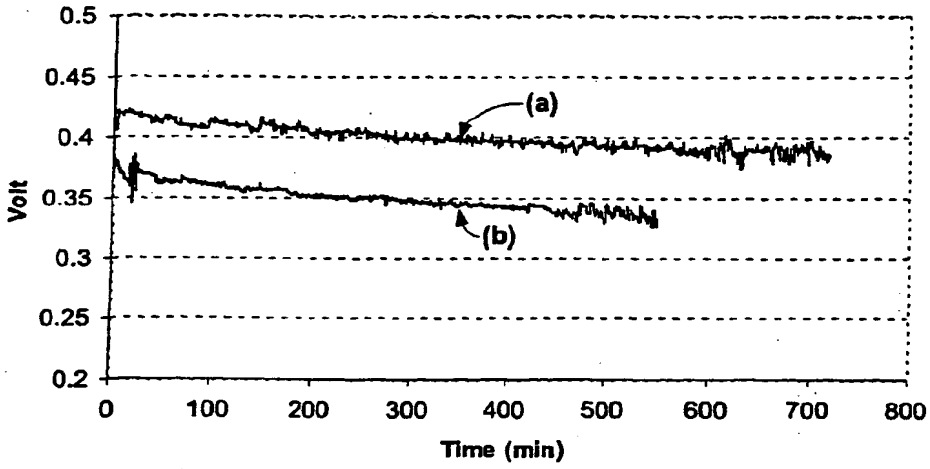

Figure 3

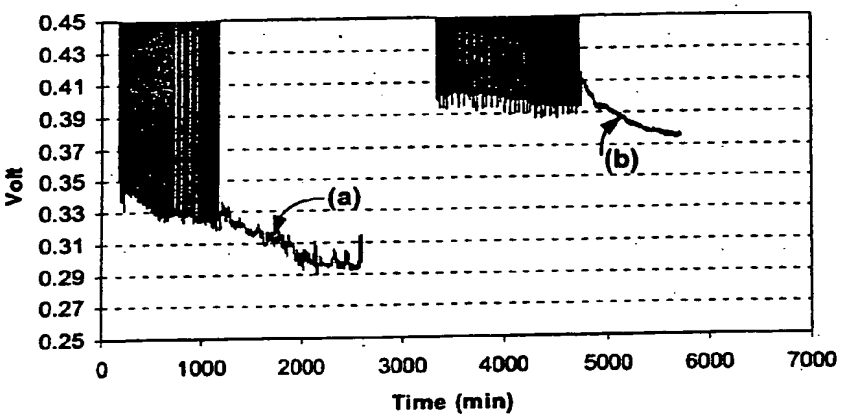

Figure 4

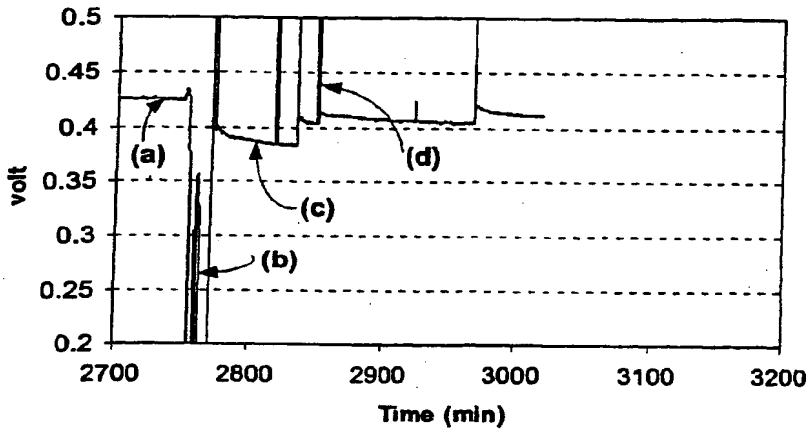

Figure 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 10 1150

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	DE 101 34 193 A (VODAFONE PILOTENTWICKLUNG GMBH) 7 February 2002 (2002-02-07) * abstract; figure 3 * * paragraphs [0015] - [0021], [0023], [0028], [0067] - [0069] *	1-10, 12-63	H01M8/04
X	DE 100 20 126 A (MANNESMANN AG) 25 October 2001 (2001-10-25) * abstract; figure 2 * * paragraphs [0003], [0004], [0012], [0020] - [0023], [0032], [0035], [0043] *	1-10, 12-63	
X	EP 0 701 294 A (BRITISH GAS PLC) 13 March 1996 (1996-03-13) * abstract; figures 1-4 * * column 3, line 3 - column 5, line 3; claim 1 *	1-10, 12-63	
P,X	WO 03/067695 A (BATTELLE MEMORIAL INSTITUTE ; VIJAYENDRAN BHIMA (US); GEORGE PAUL E (U) 14 August 2003 (2003-08-14) * page 1, line 14 - line 18 * * page 4, line 21 - page 5, line 27 * * page 7, line 22 - page 8, line 21; figures 1,3a,3c * * page 10, line 6 - line 8 * * page 11, line 3 - page 3, line 15 *	1-10,13, 17-22, 25-34, 36-47, 49-63	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H01M

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	26 July 2004	Hintermaier, F

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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EUROPEAN SEARCH REPORT

Application Number
EP 04 10 1150

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	FEDKIW P S ET AL: "PULSED-POTENTIAL IXIDATION OF METHANOL" JOURNAL OF THE ELECTROCHEMICAL SOCIETY, ELECTROCHEMICAL SOCIETY. MANCHESTER, NEW HAMPSHIRE, US, vol. 135, no. 10, 1 October 1988 (1988-10-01), pages 2459-2465, XP002069148 ISSN: 0013-4651 * page 2459 - page 2460; figure 2 * -----	1,17-19	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	26 July 2004	Hintermaier, F

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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